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Food Research International 117 (2019) 50–59

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Consumers' food selection behaviors in three-dimensional (3D) virtual reality

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ARTICLE INFO

Keywords:
Virtual reality
Virtual supermarket
Food choice
Eye-tracker
Consumer behavior

ABSTRACT

Virtual reality (VR) can be a useful tool for conducting consumer behavior experiments. The aim of this research was to examine whether people standing in front of a supermarket shelf make similar decisions and process similar information as those in front of a shelf in a VR shop. In Study 1, participants were asked to select a cereal from among 33 commercially available types of cereals placed on a shelf. One group performed the task in front of a real shelf, while the other performed it in VR. Eye-tracking data were collected for both groups. No statistically significant differences were observed in the selection of the cereals by the two groups in the two conditions. Eye-tracking data only revealed few differences in the information-seeking behavior. In Study 2, results observed using real products were replicated in VR. Participants were asked to walk through a virtual supermarket and select either a healthy cereal (healthy condition) or a tasty cereal (hedonic condition). Results showed that participants in the healthy condition paid more attention to the nutrition information than those in the hedonic condition. The results of these two experiments suggest that a VR condition wherein participants can walk around and behave as in the real world is a useful tool for conducting experiments related to food decisions.

1. Introduction

An important method for the advancement of science is the introduction of new models that allow rigorous experimental testing of causal relationships. For decades, animal models have been used as a well-defined and well-tested gold standard in nutrition research (Baker, 2008). Similarly, there is a need to develop new models in the domain of consumer behavior that allow, in a simpler way than existing models, the examination of consumer decisions in a realistic environment (Ung, Menozzi, Hartmann, & Siegrist, 2018). Virtual reality (VR) might be the technology that could enable the development of reliable models that allow efficient and rigorous research in the field of consumer research.

Virtual reality is a condition in which a user experiences and interacts with a computer-generated, virtual environment (Jason, 2016). In virtual reality, sensors capture the user's actions and the represented virtual environment is modified in accordance to the captured information. It is therefore possible for a user in virtual reality to explore a virtual shop by, for example, walking, grasping a virtual apple from a virtual shelf, and putting the apple into a virtual basket. A user exposed to virtual reality will be immersed in a simulated scene. The degree of experienced immersion depends on the fidelity with which the virtual environment is represented, particularly how closely the reaction of the virtual reality system mimics the reaction of a real environment. Among the factors affecting the degree of immersion are the number of sensory feedbacks given by the virtual reality system, such as visual, auditory; and haptic, and the delay between the action of a user and the reaction of the system latency. Head mounted displays (HMD) have become a popular technology to provide visual stimulus to the user. Today, affordable HMDs are equipped with high resolution displays (e.g. 2 displays of 1080 × 1200 pixels) subtending a visual field of 110°. Many HMDs have integrated sensors to track the position and orientation of the user in space. Additionally, controllers provided with the HMD enable the user to use her/his hands for intuitively manipulating virtual objects.

In recent years, several studies that used VR to better understand people's food choices have been published. However, a detailed study of this research shows that these experiments used VR in a rather limited manner. In some studies, participants were made to sit in front of one or several personal computer (PC) screen(s) and navigate through a supermarket using the keyboard (Bressoud, 2013; van Herpen, van den Broek, van Trijp, & Yu, 2016; Waterlander et al., 2016; Waterlander, de Boer, Schuit, Seidell, & Steenhuis, 2013; Waterlander, Jiang, Steenhuis,

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https://doi.org/10.1016/j.foodres.2018.02.033
Received 25 September 2017; Received in revised form 9 February 2018; Accepted 13 February 2018
Available online 13 February 2018

& Mhurchu, 2015; Waterlander, Scarpa, Lentz, & Steenhuis, 2011; Waterlander, Steenhuis, de Boer, Schuit, & Seidell, 2012, 2013; Waterlander, Steenhuis, & Lentz, 2010). In some other studies, an HMD was used; however, participants could not walk around or directly interact with the environment (Ledoux, Nguyen, Bakos-Block, & Bordnick, 2013; Verhulst, Normand, Lombart, & Moreau, 2017). In our view, these studies are important; nevertheless, we believe that they did not take full advantage of VR for conducting consumer research. Therefore, the goal of the presented research was to examine whether people exposed to a VR wherein they can walk around in a supermarket and pick up products from the shelves to look at the package information behave in a similar way as in the real world.

VR is of interest because it facilitates experimental studies that would be challenging or very expensive to conduct in real environments. For instance, virtual supermarkets have been used to study the influence of changes in food prices on purchase behavior (Waterlander et al., 2010; Waterlander et al., 2016; Waterlander, Steenhuis, et al., 2013) or to determine the effect on consumer behavior of the ban on tobacco advertisements and inclusion of graphic health warning signs at the points of sale (A. E. Kim et al., 2014). An obvious and crucial question here is whether consumer behavior in VR and that in a real shop are comparable. This research question has been addressed in few studies, and different parameters were used to answer this question. In one study, the participants' purchase behaviors in real shops were compared with those in a VR shop (Waterlander et al., 2015). However, the purchase behaviors of the study groups varied for the different food groups. Participants bought more dairy products, but less fruits or vegetables in the VR shop than in the real shop. A possible explanation for this finding might be that fruits and vegetables did not look as appealing in the VR as they do in a real shop. In another study, participants' behaviors in a VR store were compared with those in a real store and with those exposed to pictorial (two-dimensional [2D]) information only (van Herpen et al., 2016). Results suggest that the behavior in the VR condition was more similar to the behavior in reality than that in the pictorial condition. Nevertheless, differences were still observed between the consumers' behaviors in the physical and the VR world. The VR used in the study of van Herpen et al. (2016) was limited to the experience one has while sitting in front of a computer, not in a real supermarket. This might be the reason for the observed differences between participants' behaviors in the VR and the real world.

The reviewed literature suggests that VR might be a useful tool for consumer behavior research. Factors influencing purchase behaviors can be manipulated to a greater degree in VR than in a physical store. However, it is noteworthy that most studies we reviewed did not use a VR in which participants could walk around in the shop and stand in front of the shelf. Furthermore, participants could not grasp the products with their hands to look for additional information (e.g. nutritional information) for selecting foods. The results of the only study of its kind (to our knowledge) that used an advanced VR environment suggest that a virtual food buffet wherein participants could serve themselves VR food could be a useful research method for examining the impact of environmental cues on human nutrition behavior (Ung et al., 2018).

The aim of this research was to build on previous research in terms of the development of a VR shop and examination of whether consumer behavior in such a VR shop is comparable to that in the real world. We expected the study results to clarify whether providing a VR environment in which users can behave as similarly as possible to the real world enables the use of VR to better understand consumers' decisions. Before using VR, however, it needs to be ensured that consumers behave in a similar manner in a VR supermarket and a real supermarket. The goal of this research was to deliver a proof of concept stating that VR can be used for consumer behavior research and to test the validity of a VR 3D supermarket compared to a physical setup. Thus, we developed two different comparative studies. The first study compared the behaviors of consumers standing in front of real and virtual shelves with respect to the task of selecting cereals as per the given nutrition constraints. The second study involved the same task; however, here, the realism of the virtual environment was enhanced because the participants could walk around in the virtual supermarket as he/she would in reality.

2. Study 1

The use of VR in consumer behavior research can only be justified if peoples' behaviors in the real world and VR world are similar. Therefore, the aim of the first study was to examine the similarities or differences in consumers' behaviors in VR compared to those in the real world. The consumers' decisions should be similar in the two environments; further, their attention for different products should also be similar in order to justify the use of VR in consumer research. In addition to behavioral parameters such as the product selected by the consumer, we also examined how consumers chose a product from a shelf. Utilizing an eye-tracker, we compared the participants' gazes in the real world and in the VR. Furthermore, we compared the participants' information-seeking behaviors (i.e. the number of times participants looked at the nutrition tables) between the two conditions.

2.1. Material and methods

2.1.1. Sample size and participants

Power calculations suggest that for detecting at least a medium effect size of d = 0.80 ($R^2 = 0.138$) for a *t*-test, with $\alpha = 0.05$, and a power of 0.80, a sample of 26 persons per condition is needed (Cohen, 1988). More participants were recruited, because it was unknown how many participants would need to be excluded due to non-usable eye-tracking data. Furthermore, the data distribution may have required non-parametric tests which are often less powerful compared with parametric tests.

A convenience sample of 68 student participants was recruited. An automated system was used to record the movements of participants' right hands; therefore, left-handers were excluded from the study. Participants received CHF [Swiss Franc] 10 (about $10 US) for participating in the experiment. Informed consent was obtained prior to data collection.

Participants were randomly assigned to the real life (RL) or the VR condition. Thirty-seven people (59% men and 41% women) participated in the RL condition. Their mean age was 24 years (standard deviation [SD] = 2). Thirty-one individuals (48% men and 52% women) participated in the VR condition. Their mean age was 25 years (SD = 2). The gender distribution was not significant across the two groups ($p > .40$). The mean age between the two groups was significantly different ($p < .05$), but a mean difference of one year is not of practical relevance.

2.1.2. Experimental design

Many of the purchase decision we make are habitual decisions, we buy again what we bought last time (Hoyer, 1984). In this study, we were interested in non-habitual decisions. Therefore, we wanted to avoid a scenario wherein participants quickly select their favorite brand of cereal without spending time in the selection process. Results of a previous study suggested that if participants have to buy a product for another person, they do not make habitual decisions (Visschers, Hess, & Siegrist, 2010).

Participants were required to complete two tasks in either the real or the virtual world. The tasks were identical in both conditions, and participants were randomly assigned to one of the two conditions. In the RL condition, two shelves with three boards were used to display 33 different cereals (see Fig. 1). The shelf with the cereals was not tested in a supermarket, but in our laboratory. A similar arrangement of cereals was made in the VR market (see Fig. 1).

In the first task, the participants were asked to select cereals for a

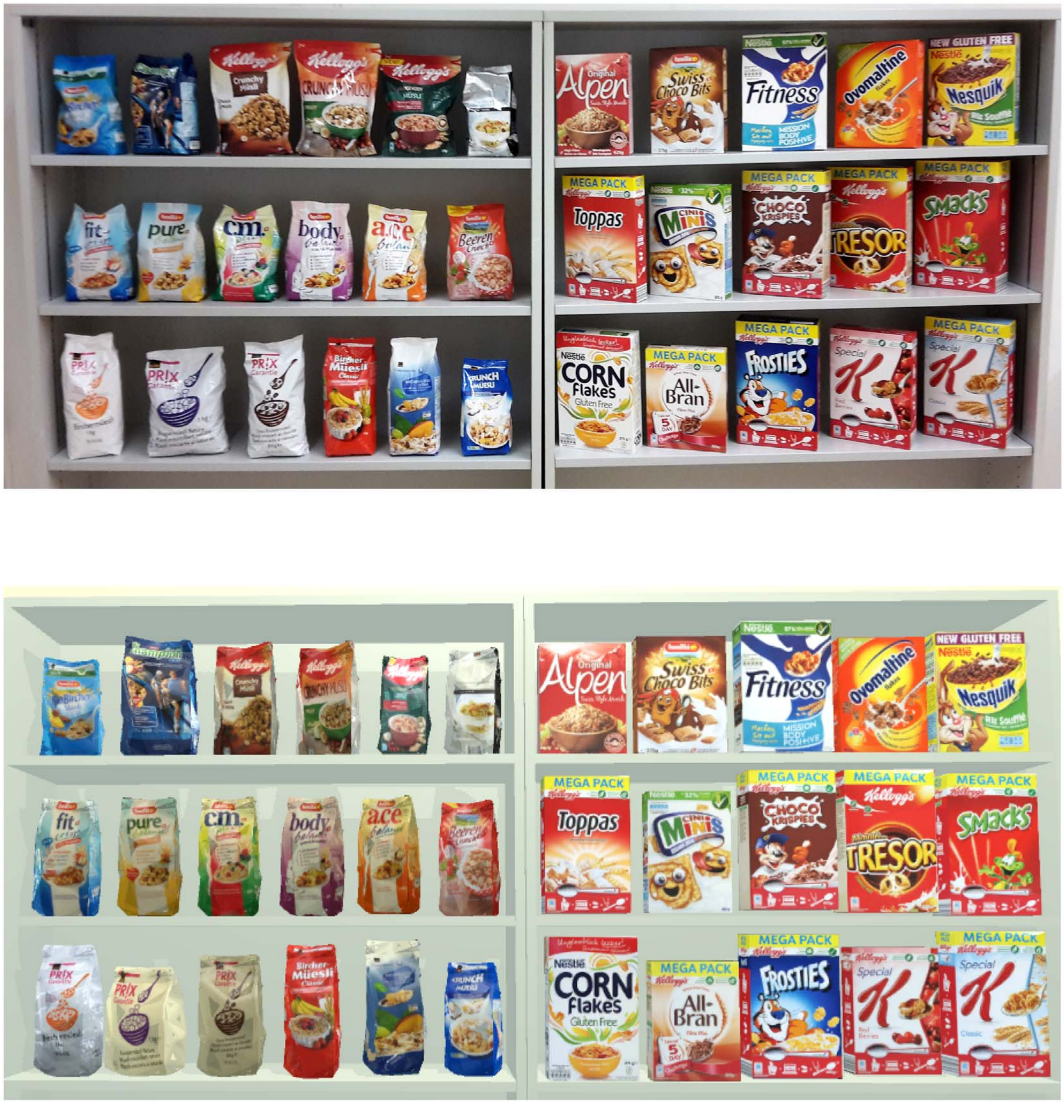

Fig. 1. Shelves and cereals used in the real life condition (upper picture) and virtual reality condition (bottom picture).

kid's camp with children aged 10–12. In the second task, participants were instructed to buy one cereal package for a friend who was on a low-sugar diet. We expected that participants would need to frequently check the nutrition information to complete this second task.

2.1.3. Procedure

In the RL condition, the eye-tracker was adjusted to the participant's head level and then calibrated. The calibration procedure required the participant to stand in front of the shelf at a distance of 2.8 m and fixate on the calibration marks printed on a large piece of paper that was placed in front of the cereals on the shelf to hide them from the participants' view. After the calibration procedure, the participant read the instructions for the first task (to buy cereals for a kid's camp). The experiment started after the paper with the calibration marks had been removed, and all cereals were visible. After the participants had chosen the cereal package in the first task, they proceeded to the second task (to find a cereal for a friend on a low-sugar diet).

In the VR condition, participants were equipped with an HMD that included an eye-tracker and a hand-tracking device. The latter served to control a participant's virtual hand when grasping a cereal box in VR. Grasping a cereal box in VR required the participant to touch the virtual box for 1.5 s. Thereafter, the box was attached to the virtual hand. The box could be released by putting it back in its original location and holding it there for another 1.5 s. Before starting the experiment, participants were given the opportunity to familiarize themselves with the VR environment and the method of grasping a box until they felt comfortable with the procedure.

Participants were informed that they could check the nutrition information for each cereal. As the resolution of the screens in the HMD does not allow the display of small fonts, because they are not readable, a separate window was shown wherein nutrition information was presented in a readable font. The window was opened by the researcher after being requested by a participant. The displayed nutrition information included information regarding energy, fat (including saturated fatty acids), carbohydrates (including sugar), protein, and sodium content.

After reading the instructions for the first task, the HMD with the eye-tracker was mounted, and the experiment was started. After the completion of the first task, the participants performed the second task.

2.2. Measurement setup

2.2.1. Real life condition

Participants' eye movements were tracked using the iViewXTM HED4 (SensoMotoric Instruments, Teltow, Germany) device. The device was attached to a bicycle helmet and installed on the participants' heads. The helmet also carried two cameras, the first one for recording the scene as viewed by the participant and the other for recording the participant's eye movements. Using the recorded eye movements, fixations were computed that were then integrated in the video recorded by the first camera.

2.2.2. Virtual reality condition

The 33 cereals used in the RL condition were modeled as virtual objects and placed in the virtual world. The textures of the virtual cereals were generated by taking photos of the real cereal boxes and attaching them to the 3D virtual objects. For this purpose, a 3ds Max 2016 (Autodesk, San Rafael, USA) was used.

The set of 33 cereals included those cereals that were packed in rigid cardboard boxes as well as those packed in plastic bags. The shape of the cardboard boxes could be reproduced easily as they were rectangular. However, the geometry of the soft packages was complex and had to be simplified to minimize the computational resources used in the VR experiment.

The VR environment was modeled using the Unity game engine version 5.4.3f1 (Unity, San Francisco, USA). The virtual environment included two shelves, 33 types of cereals, and the virtual hand, and it was displayed using an HMD (Oculus Rift DK 2, Oculus VR, Inc. Menlo Park, California, USA). The hand-tracking system used in Study 1 has been described in detail elsewhere (Ung et al., 2018).

The HMD was equipped with the binocular eye-tracking system SMI (SensoMotoric Instruments, Teltow, Germany). Recorded fixations were visualized by means of a red dot and were superimposed on a record of the virtual scene as seen by the participant. Fixations and recorded scenes were stored and analyzed visually after the measurement was completed.

2.2.3. Food products

We bought 33 different cereals from a large-scale retailer in Switzerland. There was a great variety of cereals with respect to content and brand. Some of the packages were made of cardboard boxes, while others were made of plastic (see Fig. 1).

2.3. Data processing

2.3.1. Real life condition

Videos recorded during the experiment, including the fixations were analyzed using the Interact8 software (Mangold International, Arnstorf, Germany). Fixations were detected manually while watching the recorded videos at a reduced speed. For each of the 33 cereals, so-called areas of interest (AOI) were defined. The minimum fixation time was set at 160 ms. Any fixation > 160 ms long was recorded. In addition, we recorded whether participants grasped a cereal, and whether the nutrition information table of the cereal was read.

In some cases, it was not possible to detect the fixation within the recorded videos. In such cases, datasets were discarded (three participants). In the RL condition, data from 32 participants could be analyzed successfully.

2.3.2. Virtual reality condition

The rotation of participants' heads was recorded by means of the proprietary library functions of Oculus. With respect to the recording of the position and rotation of the hand, program functions were written in Unity and integrated in the VR environment. Positions and rotations were recorded every 106 ms. The SMI eye-tracker in the HMD recorded gazes within the same time interval. Similar to that in the RL condition, AOI were defined in VR for each of the 33 virtual cereals. A function was written in Unity to record which cereal had been grasped at what time and when a participant asked for nutrition information. The number of times a package was grasped, the time required for reading the nutrition information table, and the total time spent for fixation on a particular area of interest was recorded for each area of interest and stored.

As in the RL condition, the time measurement in the VR started with the first fixation on a cereal. The time was stopped when the participant reported his/her decision to the experimenter (as in the RL condition). In the VR condition, a fixation was defined as gaze duration of at least 106 ms at the same location. The eye-tracker data was recorded and checked visually for reliability after the experiment was completed. Since a fixation is a point in the 3-dimensional space, it was not always possible to identify the particular cereal that the participant had focused on, and in cases where the fixation could not be identified, the recorded videos were replayed at 0.2 times the original speed to analyze the fixation visually.

2.4. Statistical analyses

The task completion time was computed in seconds. Relative times were used for calculating the time duration for which a participant looked at the cereal packages on each shelf. The relative fixation time was calculated based on the total fixation duration per participant; therefore, it does not include the time taken by participants to switch between cereals. Moreover, the relative fixation time does not include gaze durations shorter than the minimum fixation time. Simple counts were used for recording the frequency with which participants took out cereal packages from the shelves and for the number of times they looked at the nutrition information on the back side of the package.

3. Results

3.1. Task 1

Participants in the RL condition needed an average of 71 s (SD = 41), while those in the VR condition took an average time of 123 s (SD = 65) to fulfill the task. This difference was statistically significant, $t(61) = -3.78$, $p < .001$.

In order to examine whether participants looked in a similar way at the cereals displayed, we examined whether the time spent in the different areas of the shelves was similar in the two conditions. Therefore, we compared the relative fixation durations between the two conditions for each of the six shelves. The results shown in Table 1 suggest that there were no significant differences between these two conditions. The behavior in the RL and VR was similar with regard to the packages on which the participants focused.

Taking out a package from the shelf and looking at the nutrition information was considered to be an indicator of information-seeking behavior. In the RL condition, 10 participants (31%) looked at least once at the nutrition information, and 16 participants (51%) in the VR condition showed this information-seeking behavior. Results of the Mann-Whitney *U* test suggest that the frequency with which participants looked at the nutrition information was not significantly different between the two groups, $z = -1.68$, $p = .093$. Table 2 shows a comparison of this behavior between the two groups for each shelf. In shelf 3, the numbers were higher in the VR condition than in the RL

Table 1
Mean (SD) values and *t*-test results for relative fixation duration in real life (RL) and virtual reality (VR) conditions for task 1 in Study 1.

Shelf board	RL condition (n = 32)	VR condition (n = 31)	$t_{(61)}$ (*p*-value)
1	24.80 (15.69)	26.46 (22.76)	−0.338 (0.737)
2	15.03 (12.81)	17.50 (16.43)	−0.592 (0.556)
3	9.95 (11.88)	10.70 (15.40)	−0.217 (0.829)
4	18.90 (20.26)	22.33 (23.00)	−0.628 (0.532)
5	21.82 (21.44)	13.52 (19.64)	1.601 (0.115)
6	9.22 (7.47)	9.49 (12.23)	−0.100 (0.920)

Shelf 1 = 1st shelf on left side, shelf 4 = 1st shelf on right side, shelf 2 = 2nd shelf on left side, etc.

Table 2
Number of participants (% of n) who looked for more information regarding cereals in task 1 in Study 1.

Shelf board	RL condition (n = 32)	VR condition (n = 31)	$\chi^2_{(1)}$ (*p*-value)
1	7 (22%)	13 (42%)	2.924 (0.087)
2	6 (19%)	9 (29%)	0.918 (0.338)
3	5 (16%)	4 (13%)	0.095 (0.758)
4	2 (6%)	8 (26%)	4.510 (0.034)
5	3 (9%)	3 (10%)	0.002 (0.967)
6	1 (3%)	4 (13%)	2.061 (0.151)

Shelf 1 = 1st shelf on left side, shelf 4 = 1st shelf on right side, shelf 2 = 2nd shelf on left side, etc.

condition; however, a significant difference was only observed for shelf 4.

Finally, we examined whether there are differences between the two conditions regarding the shelf from which the cereals were chosen. The analyses ($\chi^2_{(5)} = 3.52$, $p = .62$) revealed that there were no significant differences between the two conditions.

3.2. Task 2

Participants in the RL condition needed on average 101 s (SD = 52), while those in the VR condition needed on average 120 s (SD = 50). This difference was not statistically significant, $t(61) = -1.48$, $p = .14$.

We compared the relative fixation durations between the two conditions for each of the six shelves. The results shown in Table 3 suggest that there were no significant differences between the two conditions. The behaviors in the RL and VR were similar with regard to the packages on which the participants focused.

In the RL condition, 30 participants (94%) looked at least once at the nutrition information, while in the VR condition, 31 participants (100%) showed this information-seeking behavior. The results of the Mann-Whitney *U* test suggested that the frequency with which participants looked at nutrition information was not significantly different between the two groups, $z = -1.63$, $p = .104$. Table 4 shows a comparison of this behavior between the two groups for each shelf. The results suggest that there were no significant differences between the two groups regarding how many people looked at the nutrition information of the cereals for each shelf.

Finally, we compared whether there were differences between the two conditions regarding the shelf from which the cereals were chosen. The analyses ($\chi^2_{(5)} = 6.40$, $p = .17$) suggest no significant differences regarding the decision between the two conditions.

4. Discussion

Before VR can be used in consumer research, we need to determine whether consumers' behaviors in VR are similar to those in real life. In the first study, participants were required to make two purchase decisions. The first task included the selection of cereals for a kid's camp, and the second required the selection of cereals for a person on a low-sugar diet. If people behave similarly in VR and RL, they should focus on similar areas on the shelves in the two conditions, should show similar information-seeking behaviors, and should show no difference in product selection. Overall, our results suggest that participants behaved similarly in both conditions. However, there were some significant differences between the two conditions that need to be explained.

Table 3
Mean (SD) values and t-test results for relative fixation duration the real life (RL) and virtual reality (VR) conditions for task 2 in Study 1.

Shelf board	RL condition (n = 32)	VR condition (n = 31)	$t_{(61)}$ (*p*-value)
1	24.38 (12.89)	21.36 (19.51)	0.727 (0.470)
2	21.18 (15.21)	23.42 (21.26)	−0.482 (0.632)
3	23.56 (13.93)	24.42 (25.02)	−0.170 (0.865)
4	11.36 (11.01)	12.06 (12.61)	−0.237 (0.814)
5	4.42 (5.51)	4.71 (10.44)	−0.139 (0.890)
6	15.11 (13.57)	14.02 (17.40)	0.276 (0.783)

Shelf 1 = 1st shelf on left side, shelf 4 = 1st shelf on right side, shelf 2 = 2nd shelf on left side, etc.

Table 4
Number of participants (% of n) who looked for more information regarding cereals in task 2 in Study 1.

Shelf board	RL condition (n = 32)	VR condition (n = 31)	$\chi^2_{(1)}$ (*p*-value)
1	19 (59%)	21 (68%)	0.476 (0.490)
2	12 (38%)	18 (58%)	2.670 (0.102)
3	21 (66%)	23 (74%)	0.549 (0.459)
4	11 (34%)	16 (52%)	1.911 (0.167)
5	1 (3%)	2 (6%)	0.384 (0.535)
6	17 (53%)	15 (48%)	0.141 (0.707)

Shelf 1 = 1st shelf on left side, shelf 4 = 1st shelf on right side, shelf 2 = 2nd shelf on left side, etc.

Participants in the VR condition needed more time than those in the RL condition for task 1. A major reason for this difference was the fact that slightly more participants in the VR condition looked at the nutrition information than those in the RL condition. It seems plausible that participants explored the less-familiar VR environment to a larger extent than the RL environment. When the participants were given the opportunity to familiarize themselves with the VR and test some of its exciting possibilities, as was the case for task 2, the information-seeking behavior in VR and RL appeared to be comparable. Therefore, the results of our study imply that people behave realistically in a VR condition if they have had a chance to familiarize themselves with the possibilities in this environment.

Study 1 had some limitations. For example, participants needed to ask for the display of the nutrition information; this is not a natural behavior. Further, owing to the use of different eye-tracking systems in the VR and the RL conditions, the minimum fixation time was counted differently in the two conditions. This should not be crucial for our findings, however, because we analyzed only relative fixation durations and not absolute times.

5. Study 2

Study 1 delivered some encouraging results suggesting that VR can be used for studying consumer behavior. People behaved similarly in front of a VR shelf as they did in front of a real shelf with real products. However, Study 1 has some limitations. Participants could not walk around in the VR supermarket as they can in a real shop, and participants had to request for the nutrition information to be displayed. The aim of Study 2 was to overcome these limitations of Study 1. The first goal was to further develop a VR supermarket wherein participants could walk around and find the shelf with the cereals like in a real shop. The VR in Study 2 was also more realistic because participants could look at the backside of the product to see the nutrition information. The second goal was to replicate the findings of a study conducted in the real word in the VR (Visschers et al., 2010). That study also utilized an eye-tracker, and participants had to select one out of five different cereals. The results of that study suggest that participants with a health motivation looked at the nutrition information on the food product longer than those with a taste motivation. If we can show that participants with activated health motivations behave differently in a VR shop compared with participants with activated taste motivations, it would further support the hypothesis that participants' behaviors in RL and in VR are comparable. In line with the results of a previous study (Visschers et al., 2010), we hypothesized that participants in the health motivation condition would spend more time in the shop and look more frequently at the nutrition information on the cereal packages than those in the taste motivation condition. We also expected that participants in the healthy condition would select more healthy cereals (lower in sugar and higher in fiber) compared with participants in the taste condition.

5.1. Materials and methods

5.1.1. Sample size and participants

Power calculations suggested that for a medium effect size of d = 0.80 (R^2 = 0.138), α = 0.05 (for a one-tailed *t*-test, because the direction of the effect was specified), and a power of 0.80, a sample of 20 participants for each condition was required (Cohen, 1988). More participants were recruited, because it was unknown how many participants would need to be excluded prior to data analysis (e.g. because they did not complete the required task) and because non-parametric tests have lower test-power compared with parametric tests.

A convenience sample of 50 student participants was selected. Participants received CHF [Swiss Franc] 10 (about $10 US) for participating in the experiment. Informed consent was obtained prior to data collection.

Participants were randomly assigned to the health or the taste condition. Data for three participants had to be excluded because these participants selected more than one product, and one participant behaved in a unique way, flipping all the packages on the shelf so that their backsides were visible and the nutrition information of all 15 packages could be easily compared. Twenty-three individuals (57% men and 43% women) participated in the health motivation condition. Their mean age was 28 years (SD = 6). Twenty-three participants (57% men and 43% women) participated in the taste motivation condition. Their mean age was 26 years (SD = 4). Participant age was not significantly different between the two groups, t (44) = 1.33, *ns*., and the gender distribution was the same in both conditions.

5.1.2. Experimental design and procedure

All participants were required to search for the shelf with cereals in the virtual shop (Fig. 2). Thereafter, they needed to select one cereal package, put it in the shopping cart, and proceed to the checkout section of the shop. Participants in the two conditions (healthy versus taste motivations) received different instructions. Participants in the healthy motivation condition received this directive: “Imagine that you need to buy healthy breakfast cereals for a kindergarten. In the virtual supermarket you need to search the shelf with the breakfast cereals, and then you need to select one package. Once you have selected a product, put it in the shopping cart and leave the shop.” Participants in the taste motivation condition received this directive: “Imagine that you need to bring good-tasting breakfast cereals to a breakfast with friends. In the virtual supermarket you need to search the shelf with the breakfast cereals, and then you need to select one package. Once you have selected a product, put it in the shopping cart and leave the shop.”

Before the experiment was started, participants were given the opportunity to experience VR in a different setting than shopping. A working bench with different tools was shown, and participants were encouraged to explore this environment and move the tools around. After this familiarization task, participants were shown a neutral cereal package on a shelf in VR. The task was to grasp the package and look at its backside, which included nutrition information. The aim of this task was to train participants in grasping objects in VR and show them that the nutrition information was present on the backside of the cereal packages. The same nutrition information as in Study 1 was shown. In order to make the nutrition information readable, its size was increased to cover the whole backside of the package.

5.1.3. Food products

In Study 2, 15 of the 33 products used in Study 1 were chosen. Since the computational power is much less for cardboard boxes than for soft-plastic packages, only cardboard boxes were used. The products belonged to different brands, and there were considerable differences in their sugar content.

5.1.4. Set-up of the virtual shop system

The layout of the virtual shop environment was designed utilizing the Unity version 5.4.3f1. The virtual shop system used the ReWaVE (Real Walking in Virtual Environments) system that allowed the participants to walk freely in an area of about 12.6 m × 6.3 m. The participants' positions and orientations were tracked with an Intersense IS-1200 tracking system at 180 Hz. The simulation ran on an XMG U506 with a NVIDIA 980M GPU. The laptop was in a backpack to allow participants a free walking experience. The display used was an Oculus DK2 with an SMI eye-tracking system as used in Study 1. An inbuilt subsystem of our virtual shop system recorded the head and hand positions and rotations every 0.106 s. The SMI eye-tracker also recorded

Fig. 2. A picture from the virtual reality shop. Participants were asked to select one cereal from the shelf in the center of the image.

the gaze movements in the same time-interval. In addition, an extra video capture software program simultaneously ran with the virtual shop system to record the dynamic images seen by users in the HMD. The overall system has been described elsewhere (Nescher, Huang, & Kunz, 2014).

To interact with the virtual products, the participants held an HTC Vive controller in their dominant hands. In the virtual environment, a matching hand was shown at the controller's position. To pick up a product, the participants needed to move the hand closer than 5 cm to the product. Once it was close enough, an outline was shown around the product to symbolize that the hand was in range for the product to be grabbed. This was done by using the controller's trigger button with the index finger. The selected product then started to follow the movements of the controller as long as the trigger button was pressed.

Since the range of the HTC Vive is only about 5 m × 5 m, it was not possible to provide tracking of the HTC controller for the entire ReWaVE tracking space (Nescher et al., 2014). Therefore, the HTC Vive system was set up at a specific location where the cereal shelf was located in the virtual environment. The hand tracking system was connected to a second laptop (Schenker H506, NVIDIA 970M GPU). The hand tracking position was transferred via a wireless network to the ReWaVE laptop.

6. Results

We expected that participants in the healthy condition would need more time in the shop to select the cereals and that they would select different cereals compared with the participants in the hedonic condition. In order to evaluate the healthiness of cereals, the participants would need to look for the nutritional information, and this would require more time until a purchase decision could be made. The time for completing this whole task, starting with entering the shop and ending at the checkout counter with the selected cereal after making the purchase decision, was compared for the two groups. The box-plots with the total time for the two groups are shown in Fig. 3. There were three outliers in the health condition; therefore, a non-parametric test-statistic was computed. The Mann-Whitney *U* test revealed the expected significant difference between the two conditions, $z = 2.21$, $p = .027$.

According to the study by Visschers et al. (2010), participants in the healthy condition paid more attention to the nutrition information than those in the hedonic condition; therefore, the earlier group would need more time for choosing their cereals. The first variable we used to test this behavioral difference between the two groups was the number of times a participant looked at the nutrition information of the cereals (counted when participants looked longer than 160 ms at the nutrition information). The results are shown in Fig. 4. Outliers were present in both groups. Therefore, the Mann-Whitney *U* test was used. The results of this test suggest that participants in the health condition looked at the nutrition information of cereals significantly more often than those in the hedonic condition, $z = 2.29$, $p = .022$. Finally, we examined whether the two groups differed in the time spent looking at the nutrition information. The box-plots in Fig. 5 show some outliers. Consequently, the Mann-Whitney-U test was calculated, and the results showed a significant difference between the two groups, $z = 2.61$, $p = .009$. Participants in the health condition looked longer at the nutrition information than those in the hedonic condition.

As expected, participants in the two groups selected different cereals, $\chi^2_{(11)} = 23.43$, $p = .013$. More specifically, the Mann-Whitney *U* tests suggest that participants in the health condition selected cereals with significantly less sugar ($z = 3.16$, $p = .002$) and significantly more fiber ($z = 2.70$, $p = .007$) compared with participants in the taste condition.

7. Discussion

The aim of Study 2 was to replicate a finding reported by Visschers et al. (2010) when participants chose one of several real products. Results of this study suggest that participants pay more attention to nutrition information when being asked to select a healthy cereal than when asked to select a cereal that tastes good. The results of Study 2 suggest that the same differences could be observed between the two conditions in VR. In VR, participants did not receive feedback regarding the weight of the packages, and grasping of objects differed from that in the real world. Even though the shop and the packages in VR looked similar to those in the RL condition, there were still noticeable differences between the two environments. Therefore, it was important to

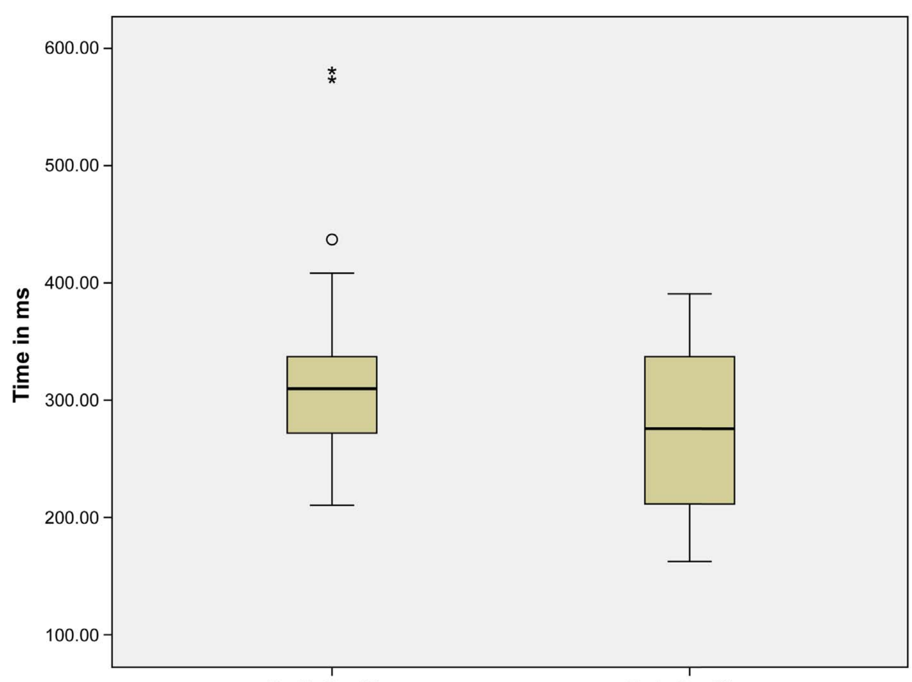

Fig. 3. Boxplots for the total time duration (ms) in the health motivation condition and the taste motivation condition.

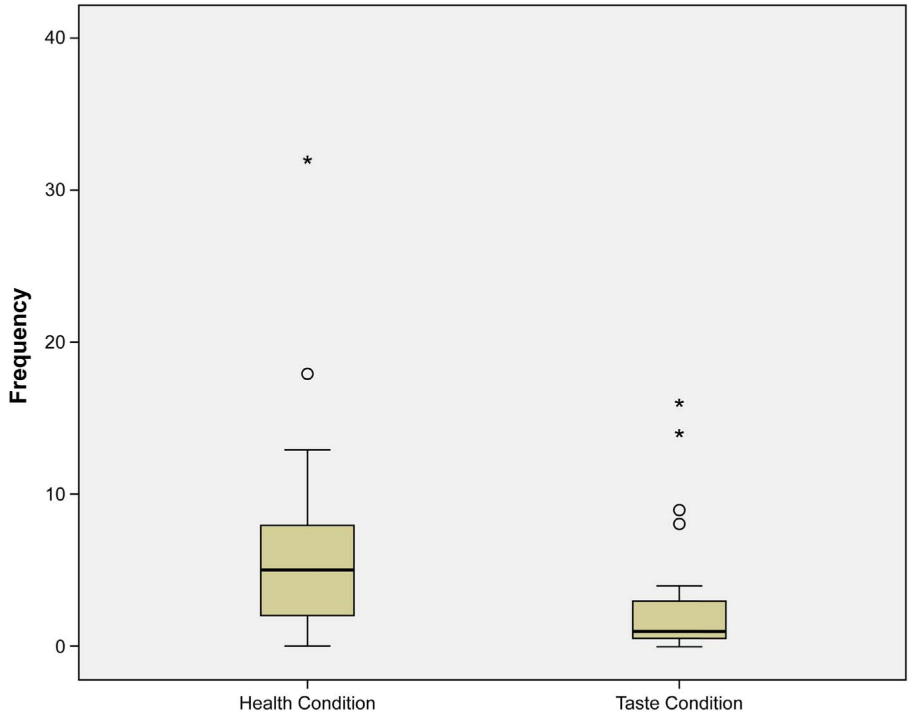

Fig. 4. Boxplots for the total number of times participants looked at the nutrition information on the food packages in the health motivation condition and the taste motivation condition.

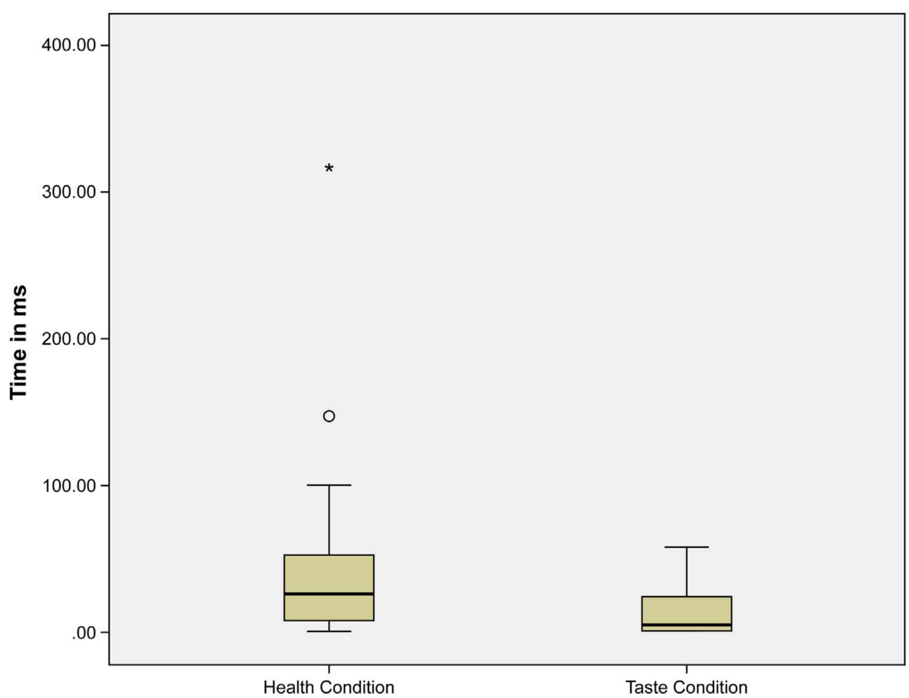

Fig. 5. Boxplots for the total time (ms) spent by participants in looking at the nutrition information in the health motivation condition and the taste motivation condition.

demonstrate that people behave similarly in VR and RL conditions.

8. General discussion

Many studies that have used VR in food research thus far have used limited systems. In many studies, participants were simply sitting in front of a computer screen and navigating through a supermarket using a keyboard (Bressoud, 2013; van Herpen et al., 2016; Waterlander et al., 2010; Waterlander et al., 2011; Waterlander et al., 2012; Waterlander et al., 2015; Waterlander et al., 2016; Waterlander, de Boer, et al., 2013; Waterlander, Steenhuis, et al., 2013). In other studies, immersive technologies were used to examine how the context influenced the sensory evaluations (Bangcuyo et al., 2015; S. E. Kim, Lee, & Kim, 2016). However, the VR environment used in these studies was also limited because participants could not interact with the VR environment.

In this study, a VR environment was used wherein participants could freely walk around, use their hands for taking food packages off a shelf, and search for information on the packages. In other words, we simulated aspects of the environment that are important for a better understanding of people's decision-making processes. We believe that we used a more realistic VR environment than those used in other food research studies. In our view, this is an important next step because the VR condition that we used allowed an examination of the process (i.e. how people search for information) in a decision task as opposed to just the outcome (i.e. which product was chosen).

It is important to demonstrate that participants' behavior in VR is similar to that in the real world. In both studies, we found very similar behaviors in the VR condition as those observed in the real world. Our results are encouraging, and they suggest that VR is a useful research method that can be used for simulating a supermarket.

There are some possible differences between RL and VR that need to be considered, however. Participants seem to spend more time in VR compared with RL. Participants may not be familiar with VR and this may have an impact on their behavior in VR. The results of Study 1 suggest that some familiarization with VR is necessary, otherwise participants are more focused on exploring VR than in the task they are asked to solve. As the findings of Study 2 suggest, an unrelated scenario can be used to familiarize participants with VR, helping them keep their focus on the tasks.

Nevertheless, some study limitations need to be addressed. Convenience samples were used, and only young people participated in our two studies. These people may have less experience in grocery shopping compared with older people. The sample sizes were similar as in other VR studies (Ledoux et al., 2013; Waterlander et al., 2015), and allowed the detection of medium to large effects (small differences are of less practical relevance). Nevertheless, we cannot rule out that there are small differences between VR and RL that we could not uncover with our relatively small samples. In Study 1, participants more often looked at the nutrition information in the VR compared with the RL. This effect was only marginally significant, and with a larger sample this effect might be significant. We should also mention that such a result may not be a problem, given that we still found significant differences in time spent looking for nutrition information across conditions in Study 2.

An important limitation is the small set of tasks examined the present study. Furthermore, the nutrition information had to be differently presented in VR compared with RL because, given the resolution in VR, the text would not have been readable otherwise. The information in VR may, therefore, have caught more attention compared with RL. Based on this study, we cannot rule out that the nutrition information in VR may have had a stronger effect on the perception of the cereals compared with RL. Another limitation of this study is that we only focused on one product category (i.e. cereals).

Additional validation studies of VR supermarkets would be desirable. Future studies should address whether older individuals also behave similarly in VR and RL conditions. Another important research question is whether the shopping basket for the weekly groceries in a real supermarket is comparable to a VR supermarket.

VR will allow the performance of experiments that would not have been possible in the real world. One could examine, for example, how mood influences people's food selections (Koster & Mojet, 2015). Another important research question that could be addressed would be how gaze behavior can be used to predict consumer behavior in a supermarket (Jantathai, Danner, Joechl, & Durrschmid, 2013). We could also examine how food advertising and point-of-sale activities influence consumer behavior (Vukmirovic, 2015). These are only few examples to illustrate the remarkable potential of VR in food and consumer research.

9. Conclusions

The results of the two studies show that, in regard to evaluating and selecting foods, behavior in VR is in many aspects comparable to behavior in RL. VR seems to be a promising tool that could be used for various experimental studies examining people's food choices in a controlled environment. We also observed some differences between VR and RL, however. Future research needs to address how relevant these differences are and what the limitations are for the use of VR in research examining people's food decisions.

Acknowledgments

We are grateful for the financial support from Schweizerischer Nationalfonds (project 205121_153243).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodres.2018.02.033.

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